The Geometry of Vision: Hermann Maertens' Optical Scale for a Deterministic Architecture

La Geometría de la Visión: la Escala Óptica de Hermann Maertens para una Arquitectura Determinista

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Abstract

In 1870s the German architect Hermann Eduard Maertens grounded his Optical Scale research on Hermann Helmholtz and Franciscus Donders' works about the physiology of vision and engrafted it in the tradition of Renaissance perspective and proportion theory's applications to architecture and urban planning. This article describes the scientific core of his approach, in the context of a general revision of aesthetic enjoyment of artworks and a deterministic reorientation of human knowledge toward the industrial production; his elaboration of a triad of visual angles to determine size and organization of space according to visual targets; the diffusion of visual cones as a graphic tool to include perceptual values in the project; the immediate success of his formula among architects and urban planners but, at the same time, the critical reception of his static concept of urban perception; the means of transmission of his ideas in the XX century and their often unaware long-term influence on some postwar years researches.

Keywords

Hermann Maertens, Optical Scale, Visual Perception, Visual Planning, Science and Architecture, Perspective

Resumen

En 1870 el arquitecto alemán Eduard Maertens basó su investigación en Escala Óptica en los trabajos de Hermann Helmholtz y Franciscus Donders sobre fisiología de la visión, injertado en la tradición de la perspectiva renacentista y en las aplicaciones en arquitectura y planeamiento urbano de la teoría de las proporciones. Este artículo describe el fundamento científico de este enfoque, en el contexto de una revisión general del disfrute estético de las obras de arte y una reorientación determinista del conocimiento humano hacia la producción industrial; su elaboración de una tríada de ángulos visuales para determinar el tamaño y la organización del espacio según objetivos visuales; la difusión de conos visuales como una herramienta gráfica para incluir valores perceptuales en el proyecto; el éxito inmediato de su fórmula entre arquitectos y urbanistas pero, al mismo tiempo, la recepción crítica de su concepto estático de percepción urbana; los medios de transmisión de sus ideas en el siglo XX y su habitualmente inconsciente y prolongada influencia en algunas investigaciones de los años de postguerra.

Palabras clave

Hermann Maertens, Escala Óptica, Percepción Visual, Planeamiento Visual, Ciencia y Arquitectura, Perspectiva

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> … buildings about it should answer in some proportion to the open area in the middle, that it may not seem too large, by means of the lowness of the Buildings, nor too small, from their being too high[1].
>
> Leon Battista Alberti, *The Ten Books of Architecture*, half of XV Century

Introduction

In the second half of the XIX century, art history, aesthetic reflection and psychology of perception often crossed issues and methods, implicitly seeking for a mutual legitimacy and a developmental orientation. In the fundamental *Der Stil* (1860-63), Gottfried Semper had linked the three spatial moments of aesthetic perception to the human body: height, width and depth were synonymous with symmetry, proportion and direction. A few years later, Robert Vischer had exposed his idea of *Einfühlung* or Theory of Empathy in *Über das optische Formgefühl: and Beitrag zur Ästhetik* (1873), correlating the perceived form with the subject, his mood and his personal predisposition to grasp the meanings and sensations.

The work of the German architect Hermann Eduard Maertens[2] (1823-1898), and in particular his research on the Optical Scale or *Optische-Maassstab* in 1870s and 1880s, lies in a common area with the various scientific and artistic disciplines that were evolving rapidly in those years. Thus, his work can be analyzed from both the point of view of visual physiology and cognitive psychology, as well as in an architectural and urban planning key. This enquiry focuses particularly on the scientific base of his studies and the reception of his studies on the correct visual distance in the field of urban studies and design, often by unaware scholars and designers of the XX century.

Visual perception at the end of the XIX century

The picture of scientific studies at the end of the XIX century is particularly lively thanks to the engagement of Hermann Helmholtz (1821-1894). His research on the physiology of the eye and vision was part of the activities of the Berlin Physical Society, whose members were concerned with the measurement and representation of space and time. They elaborated, used and refined tools such as "Telegraphy, imaging devices, electromagnetic devices for time measurement, and graphic display of temporal processes connected with light, sound, or neurophysiological phenomena"[3] and, through the pages of the journal *Die Fortschritte der Physik*, they undertook to find application fields, for example, for their methods of measuring small time intervals through graphical devices capable of enhancing shifts or imperceptible transformations[4].

In his treatise entitled *Handbuch der Physiologischen Optik* (1856-1867), Helmholtz not only had pointed out that the human eye sees in detail only a small fraction of the visual field but he also established how this fraction could be measured. Thus, he determined the unit of measurement in the evaluation of the vision, establishing that the size of the figures represented should be subtracted to one-minute arc size at the conventional reading distance.

The work of the Dutch Franciscus Donders (1818-1889), the most accredited founder of the science and art of vision measurement, with significant relapse on ophthalmology, has been engaged properly on this fundamental observation. Already before his lucky O*n the Anomalies of Accommodation and Refraction of the Eye* (1864) translated into French, German and Italian, Donders had coined the term "visual acuity" to measure and describe the sharpness of vision through the relationship between the result of subject and the average result of the popu-

1 Leon Battista Alberti, Cosimo Bartoli, and Giacomo Leoni, *The Ten Books of Architecture: the 1755 Leoni Edition* (New York: Dover Publications, 1986), 173.

2 Hermann Eduard Maertens was born in Halberstadt on August 16th, 1823. He studied architecture at the Academy of Fine Arts in Berlin. He was employed in the construction offices of Prussian cities and he taught as an Assistant professor at the Königliche Landwirthschaftliche Akademie Poppelsdorf in Bonn. In 1874 he married Clara Anna Pauline Hermann (1846-1908) who gave him two sons, Paul and Max. Then he worked as Military Architect (*Garnisonbaumeister*) in Cologne. He also had a private practice in Bonn, where in 1890 he contributed in restoring Ludwig van Beethoven's birth-house and converting it into a museum. He died in Bonn in 1898.

3 Timothy Lenoir, "Helmholtz and the Materialities of Communication", *Osiris* 9 (1994): 188.

4 Helmholtz defined it as *Mikroskopie der Zeit*, the microscope of time.

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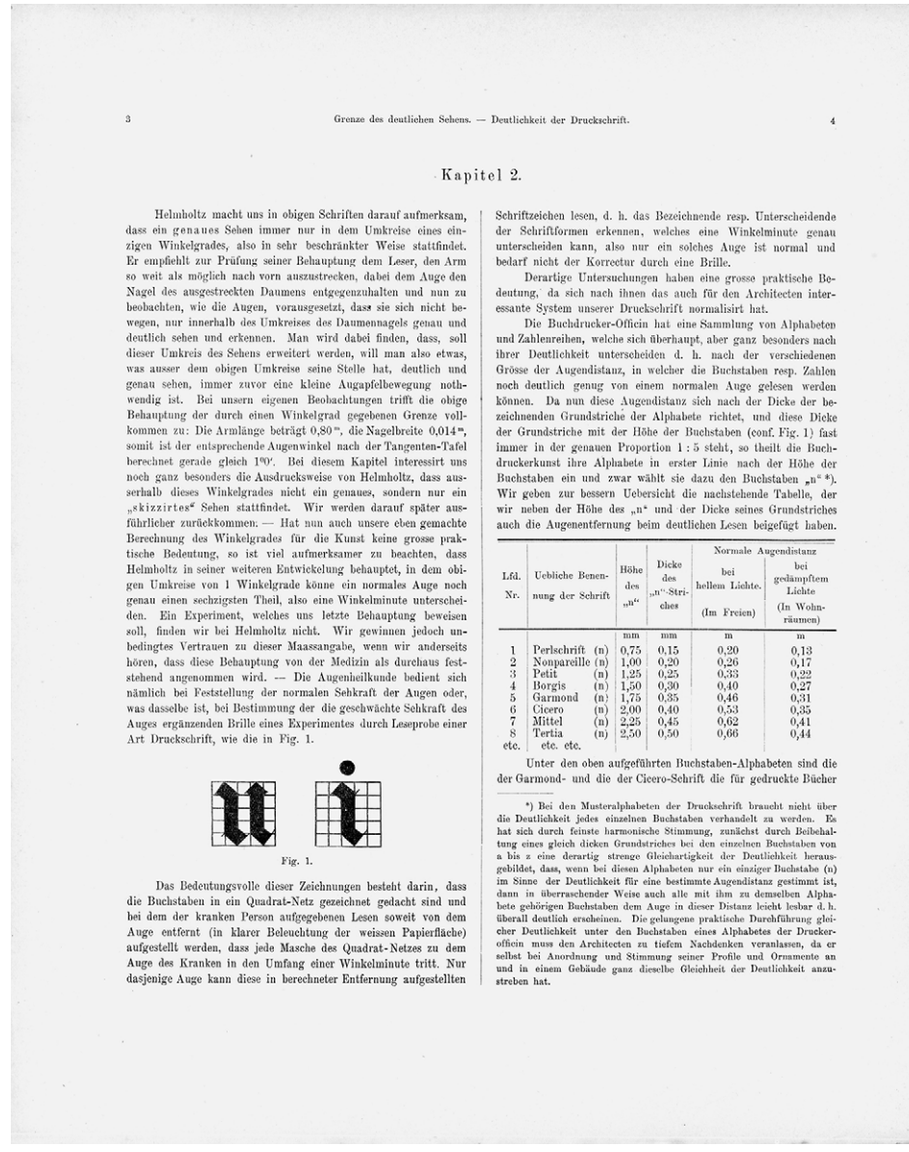


3 Grenze des deutlichen Sehens. — Deutlichkeit der Druckschrift. 4

Kapitel 2.

Helmholtz macht uns in obigen Schriften darauf aufmerksam, dass ein genaues Sehen immer nur in dem Umkreise eines einzigen Winkelgrades, also in sehr beschränkter Weise stattfindet. Er empfiehlt zur Prüfung seiner Behauptung dem Leser, den Arm so weit als möglich nach vorn auszustrecken, dabei dem Auge den Nagel des ausgestreckten Daumens entgegenzuhalten und nun zu beobachten, wie die Augen, vorausgesetzt, dass sie sich nicht bewegen, nur innerhalb des Umkreises des Daumennagels genau und deutlich sehen und erkennen. Man wird dabei finden, dass, soll dieser Umkreis des Sehens erweitert werden, will man also etwas, was ausser dem obigen Umkreise seine Stelle hat, deutlich und genau sehen, immer zuvor eine kleine Augapfelbewegung nothwendig ist. Bei unsern eigenen Beobachtungen trifft die obige Behauptung der durch einen Winkelgrad gegebenen Grenze vollkommen zu: Die Armlänge beträgt 0,80 m, die Nagelbreite 0,014 m, somit ist der entsprechende Augenwinkel nach der Tangenten-Tafel berechnet gerade gleich 1°0'. Bei diesem Kapitel interessirt uns noch ganz besonders die Ausdrucksweise von Helmholtz, dass ausserhalb dieses Winkelgrades nicht ein genaues, sondern nur ein „skizzirtes" Sehen stattfindet. Wir werden darauf später ausführlicher zurückkommen. — Hat nun auch unsere eben gemachte Berechnung des Winkelgrades für die Kunst keine grosse praktische Bedeutung, so ist viel aufmerksamer zu beachten, dass Helmholtz in seiner weiteren Entwickelung behauptet, in dem obigen Umkreise von 1 Winkelgrade könne ein normales Auge noch genau einen sechzigsten Theil, also eine Winkelminute unterscheiden. Ein Experiment, welches uns letzte Behauptung beweisen soll, finden wir bei Helmholtz nicht. Wir gewinnen jedoch unbedingtes Vertrauen zu dieser Maassangabe, wenn wir anderseits hören, dass diese Behauptung von der Medizin als durchaus feststehend angenommen wird. — Die Augenheilkunde bedient sich nämlich bei Feststellung der normalen Sehkraft der Augen oder, was dasselbe ist, bei Bestimmung der die geschwächte Sehkraft des Auges ergänzenden Brille eines Experimentes durch Leseprobe einer Art Druckschrift, wie die in Fig. 1.

Fig. 1.

Das Bedeutungsvolle dieser Zeichnungen besteht darin, dass die Buchstaben in ein Quadrat-Netz gezeichnet gedacht sind und bei dem der kranken Person aufgegebenen Lesen soweit von dem Auge entfernt (in klarer Beleuchtung der weissen Papierfläche) aufgestellt werden, dass jede Masche des Quadrat-Netzes zu dem Auge des Kranken in den Umfang einer Winkelminute tritt. Nur dasjenige Auge kann diese in berechneter Entfernung aufgestellten Schriftzeichen lesen, d. h. das Bezeichnende resp. Unterscheidende der Schriftformen erkennen, welches eine Winkelminute genau unterscheiden kann, also nur ein solches Auge ist normal und bedarf nicht der Korrectur durch eine Brille.

Derartige Untersuchungen haben eine grosse praktische Bedeutung, da sich nach ihnen das auch für den Architecten interessante System unserer Druckschrift normalisirt hat.

Die Buchdrucker-Officin hat eine Sammlung von Alphabeten und Zahlenreihen, welche sich überhaupt, aber ganz besonders nach ihrer Deutlichkeit unterscheiden d. h. nach der verschiedenen Grösse der Augendistanz, in welcher die Buchstaben resp. Zahlen noch deutlich genug von einem normalen Auge gelesen werden können. Da nun diese Augendistanz sich nach der Dicke der bezeichnenden Grundstriche der Alphabete richtet, und diese Dicke der Grundstriche mit der Höhe der Buchstaben (conf. Fig. 1) fast immer in der genauen Proportion 1 : 5 steht, so theilt die Buchdruckerkunst ihre Alphabete in erster Linie nach der Höhe der Buchstaben ein und zwar wählt sie dazu den Buchstaben „n" *). Wir geben zur bessern Uebersicht die nachstehende Tabelle, der wir neben der Höhe des „n" und der Dicke seines Grundstriches auch die Augenentfernung beim deutlichen Lesen beigefügt haben.

Lfd. Nr.	Uebliche Benennung der Schrift	Höhe des „n"	Dicke des „n"-Striches	Normale Augendistanz bei hellem Lichte. (Im Freien)	Normale Augendistanz bei gedämpftem Lichte (In Wohnräumen)
		mm	mm	m	m
1	Perlschrift (n)	0,75	0,15	0,20	0,13
2	Nonpareille (n)	1,00	0,20	0,26	0,17
3	Petit (n)	1,25	0,25	0,33	0,22
4	Borgis (n)	1,50	0,30	0,40	0,27
5	Garmond (n)	1,75	0,35	0,46	0,31
6	Cicero (n)	2,00	0,40	0,53	0,35
7	Mittel (n)	2,25	0,45	0,62	0,41
8	Tertia (n)	2,50	0,50	0,66	0,44
etc.	etc. etc.				

Unter den oben aufgeführten Buchstaben-Alphabeten sind die der Garmond- und die der Cicero-Schrift die für gedruckte Bücher

*) Bei den Musteralphabeten der Druckschrift braucht nicht über die Deutlichkeit jedes einzelnen Buchstaben verhandelt zu werden. Es hat sich durch feinste harmonische Stimmung, zunächst durch Beibehaltung eines gleich dicken Grundstriches bei den einzelnen Buchstaben von a bis z eine derartig strenge Gleichartigkeit der Deutlichkeit herausgebildet, dass, wenn bei diesen Alphabeten nur ein einziger Buchstabe (u) im Sinne der Deutlichkeit für eine bestimmte Augendistanz gestimmt ist, dann in überraschender Weise auch alle mit ihm zu demselben Alphabete gehörigen Buchstaben dem Auge in dieser Distanz leicht lesbar d. h. überall deutlich erscheinen. Die gelungene praktische Durchführung gleicher Deutlichkeit unter den Buchstaben eines Alphabetes der Druckerofficin muss den Architecten zu tiefem Nachdenken veranlassen, da er selbst bei Anordnung und Stimmung seiner Profile und Ornamente an und in einem Gebäude ganz dieselbe Gleichheit der Deutlichkeit anzustreben hat.

[Fig. 1] Herman Snellen's Optotypes as the elementary particle of the visual perception
Fuente: Hermann Maertens, *Der Optische-Maassstab*, 1884, 3.

lation. The most famous result of his studies consists of the so-called optotypes, a series of graphic symbols on a 5x5 square matrix that his colleague surgeon Hermann Snellen (1834-1908) translated into letters, perfected and published in the form of the homonymous table that still today is on the wall of every ophthalmologists' room. On the basis of that table, Snellen defined normal the human ability to recognize an optotype when it underwent 5 minutes of arc and then to discriminate a single stroke length of 1 minute arc[5].

Even today the definition of the limits of the "representable", which is generally adopted to determine what is to be drawn and what to be excluded at the different scales of architectural representation, is basically the result of the observations of those scholars. Quite appropriately, since the first edition of the Hermann Maertens' treatise, the first illustration included in the text is a pair of Gothic characters over the 5x5 grid of Donders and Snellen: the letters "u" and "i" are there to indicate how all his monumental work is based on the ability of ocular resolution and visual acuity to distinguish, respectively, a single line and to two lines divided by a narrow blank space [Fig. 1].

The Optical Scale of Hermann Maertens

In 1877 Hermann Maertens published the first edition of *Der Optische-Maassstab or Die Theorie und Praxis des ästhetischen Sehens in den bildenden in the Auf Grund der Lehre der physiologischen Optik*, that is "The Optical Scale or Theory

5 Herman Snellen, *Optotypi ad visum determinandum* (Utrecht: Van de Weijer, 1862). In 1875, Snellen changed the measuring system from feet to meters, ranging from 20/20 to 6/6 (currently the measurement on base 20 is used in the United States, while the one on base 6 is used in Great Britain). In the same year Ferdinand Monoyer proposed replacing the fraction of Snellen with the decimal equivalent, or 10/10. Decimal notation is simpler and allows to compare the different values of visual acuity detected at different distances.

[Fig. 2] Cover of the second edition of Hermann Maertens' *Der Optische-Maassstab*
Fuente: Hermann Maertens, *Der Optische-Maassstab*, 1884, Cover.

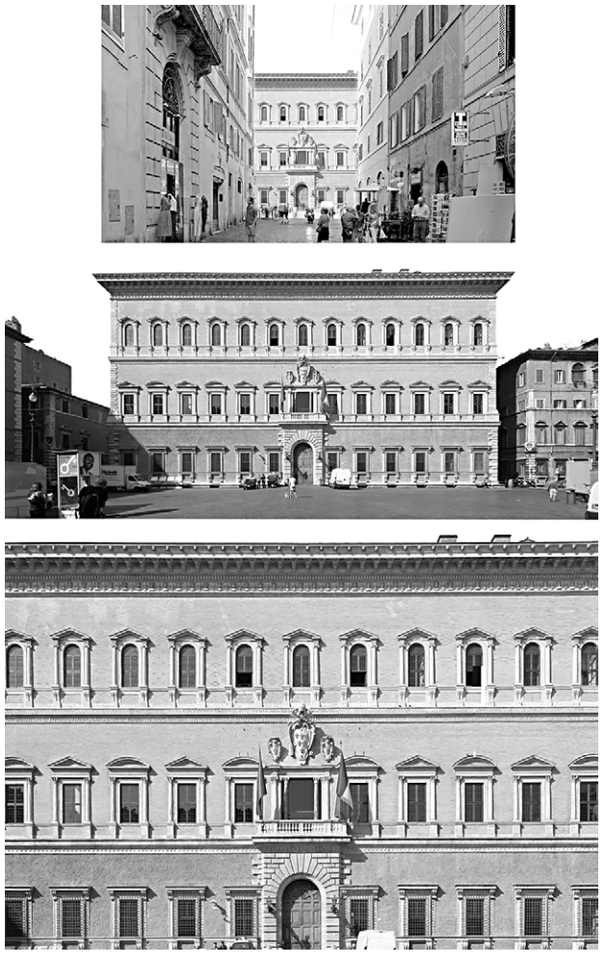
and Practice of the Aesthetic Vision of the Arts on the Basis of Optical Physiology". The title, together with the epigraph, is an explicit homage to Helmholtz's work as well as an attempt to share his discoveries about visual perception with artists. According to Maertens, the artists could no longer afford to ignore that an aesthetic judgment is determined by the first impression of a work and that this is the result of a generally fixed gaze, in which a fundamental role is played by the normal or direct vision, that is extremely limited if compared to the general human field of view.

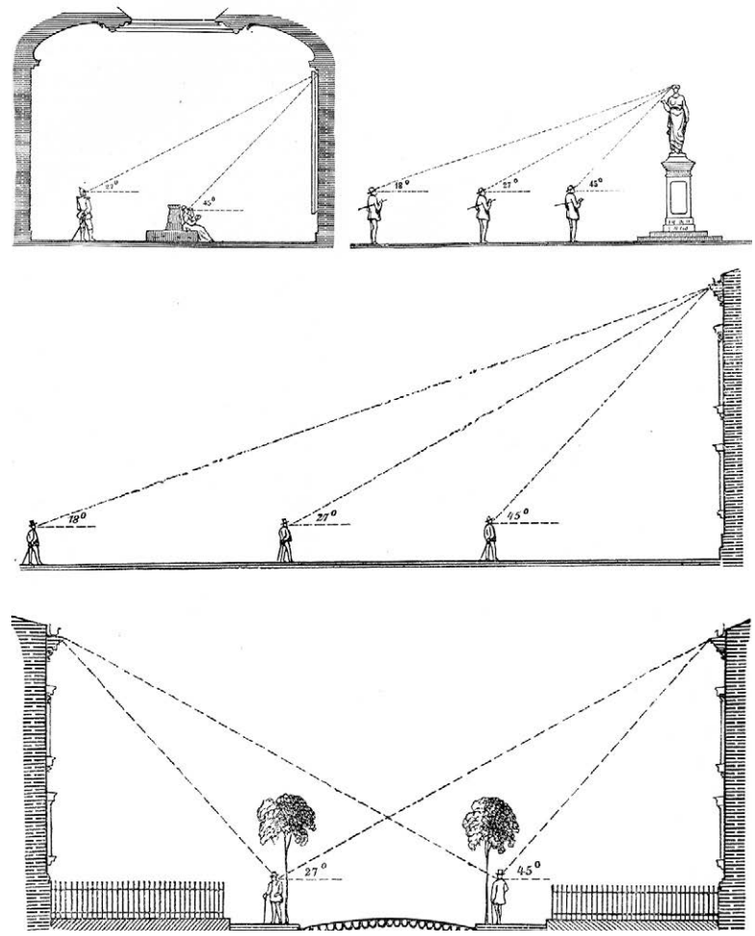
By reading the front page of the first edition one can understand the vastness of Maerten's ambitious project of a scientific reform of art, architectural and urban planning. His book was addressed to "Architekten, Maler, Bildhauer, Musterzeichner, Modelleure, Stukkateure, Möbelfabrikanten, Landschaftsgärtner und Kunstfreunde".[6] Within seven years, Maertens passed from the 146 pages (63 illustrations, 14 tables and 4 lithographed plates) of the first edition to the 434 pages (73 illustrations, 12 tabs and 1 plate) of the second edition (1884), in which he synthetized in "Ateliers und Kunstschulen der Architekten, Bildhauer etc."[7] the list of his target interlocutors to emphasize the didactic priority of his work [Fig. 2].

As a descendant of the Renaissance perspective critical tradition convinced of the pervasiveness of the visual effect on proportional mathematics, over twenty years Maertens took on the task of collecting – and often surveying on his own – detailed metric data of dozens of European monumental complexes with the pur-

6 Hermann Eduard Maertens, *Der Optische-Maassstab oder die Theorie und Praxis des ästhetischen Sehens in den bildenden Künsten* (Bonn: Max Cohen & Sohn., 1877), Front page.

7 Hermann Eduard Maertens, *Der Optische-Maassstab oder die Theorie und Praxis des ästhetischen Sehens in den bildenden Künsten*, 2nd ed. (Bonn: Max Cohen & Sohn., 1884), Front page.





[Fig. 3] Approaching Palazzo Farnese in Rome. The three pictures have been shot with a distance from the palace resulting from the application of 18, 27 and 45 degrees visual angles suggested by Maertens.
Fuente: Elaboration by the author.

[Fig. 4] The 18, 27, and 45 degrees visual angles in the contemplation of pictures in a gallery, of a monument in a garden, of the facade of a building, and in designing a street section.
Fuente: Hermann Maertens, *Der Optische-Maassstab*, 1884, figg. 8, 9, 10, 15.

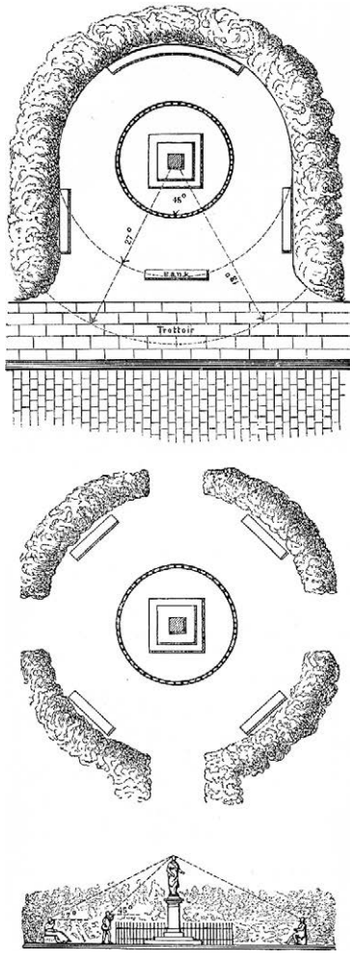
pose of establishing the operation of visual perception in the urban environment with mathematical certainty. Basing on these documents, Maertens elaborated a kind of system of optical proportions that translated the secret formal relationships of architectural spaces into easy geometric ratios.

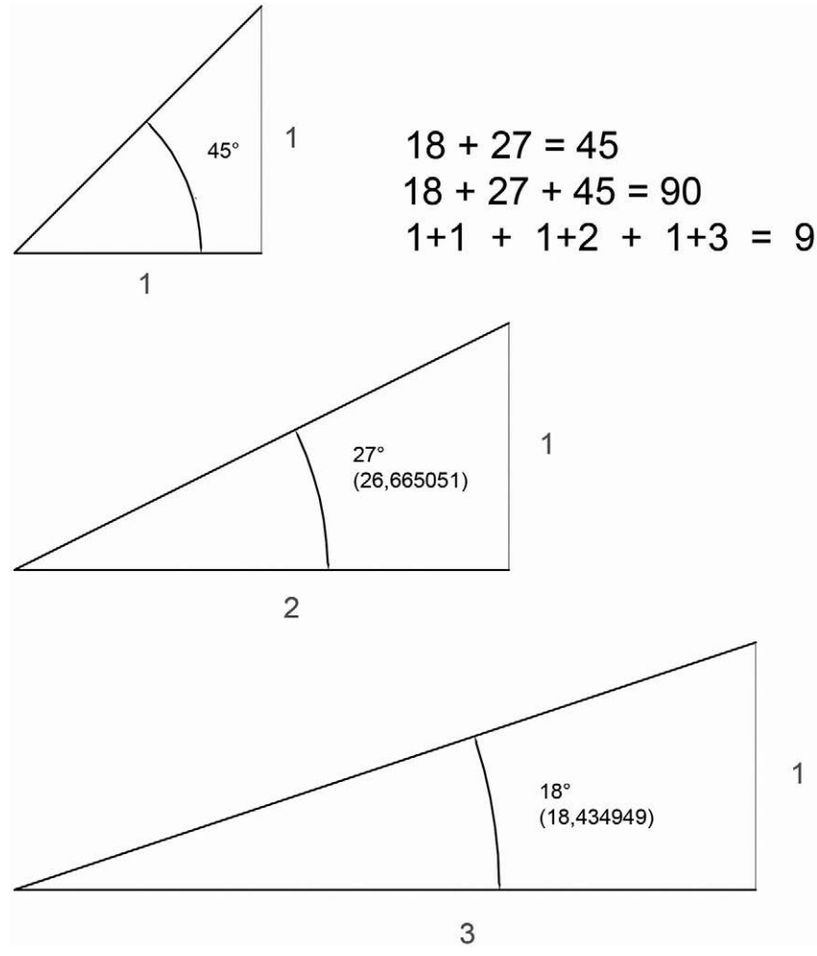
A triad of visual angles

Maertens' approach to the problem of the visual relationship between the façade of a building and the space before it is expressed by a triad of visual angles that set distances and thresholds for three different ways of contemplating architecture. He fixed these angles in a series of profile illustrations: 18° is the angle of field in which an artwork or a building appears to be part of the surrounding context around it in a whole image; when it is seen under a visual angle of 27°, it appears in its integrity and completeness; under a visual angle of 45° or more, the observer's attention is conquered by the details [Fig. 3].

To provide historical and operational validity to his conjectures, Maertens worked on two parallel tracks: on the one hand, he elaborated a number of perceptual analyzes of Italian, French and German squares and monumental historical complexes; on the other, he proposed a series of typical design situations to demonstrate how his Optical Scale would optimize the placement and dimensioning of artworks, signs, screens and pathways within a museum room, a street section, a garden or a palace [Fig. 4]. His analyzes naturally needed to demonstrate the validity of the approach and to make the system more appealing especially to designers who pursued the inscrutable canons of space harmony of so many historical sites.

While the numerical data after the analyzes resulted into complex oversized tables for the benefit of the most resolute historians, the meta-design devices are illustrated by a series of drawings in section and, rarely, in plan. For example, the com-





[Fig. 5] Designing a garden around a monument through 18, 27 and 45 degrees visual angles.
Fuente: Hermann Maertens, *Der Optische-Maassstab*, 1884, figg.11, 12.

[Fig. 6] Numeric properties of the angular triad and corresponding ratios. Diagram by the author.
Fuente: Elaboration by the author.

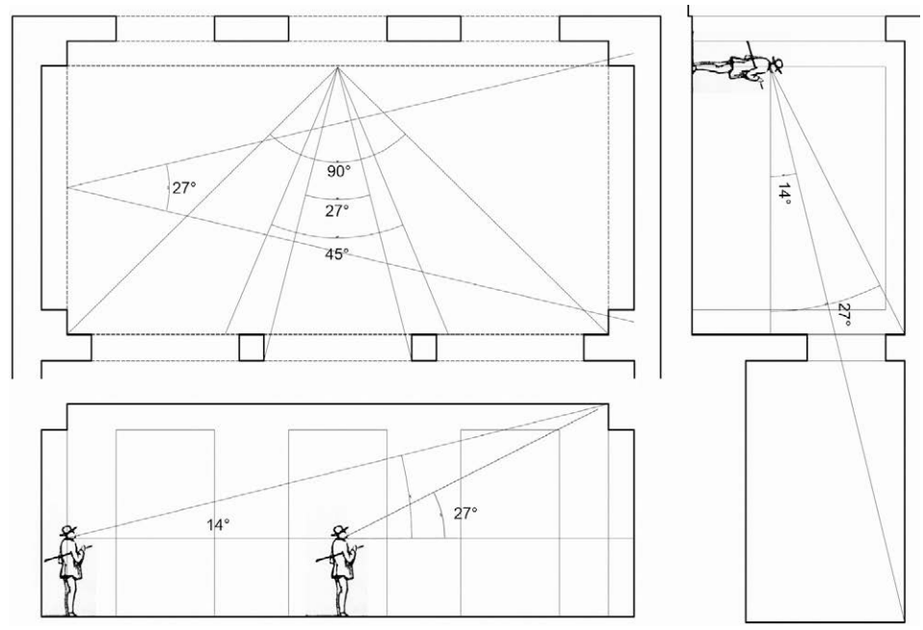
bination of plan and section of a garden organized around a monument shows the *Maaastab*'s efficiency in determining the size and position of the protection fence, the crown of flowerbeds and the path of passage according to visual concentric circles derived by the application of the visual angles of 45, 27 and 18 degrees of the people walking or sitting down around the monument itself [Fig. 5].

Maertens proposed investigations and integration of optical correction devices, which were also an heritage of an historical architectural practice at risk of extinction. A separate discourse would deserve the architectural detail. He analyzed it through the same readability parameters that indicate the correct size of the letters on a road sign to be seen in the distance. He had established that, apart from some correction coefficients due to brightness and chromatic contrast effects, the body of the typographical character should be the 3.450th part of the maximum reading distance[8]. He then devoted himself to the elements of classical moldings and their almost imperceptible formal variations in the highest parts of a temple or a church. In the size of the triglyphs or thin dentils, Maertens felt he had found the equivalent of Donders' optotypes, the limit case in which the visual acuity of the observer was to be tested.

Although Maertens measured the visual cone with angular values, it is important pointing out that his angular triad refers to the fundamental ratios of 1: 3, 1: 2 and 1: 1, the divisions resulting maliciously approximated at 18, 27 and 45. 45 is actually the sum of 18 and 27 and the three numbers are in the ratio of 2: 3: 5 among themselves, having 9 as a common denominator [Fig. 6][9]. This arithmetical relationship suggests that Maertens, aspiring to discover and disseminate a law with a universal value, felt it was necessary to design it with some elementary geometric relationship, in order to dress it with some absolute or divine attribute or just to make it easy to remember and apply.

8 Maertens, *Der Optische-Maassstab,* 1884, 4.

9 There is also a fourth ratio, equal to 1:6, approximated to 72°, which would mark the threshold of the panoramic view but it was quite secondary to Maertens' main interests.



[Fig. 7] Analysis of the living room of Adolf Loos' Villa Mueller in Prague through. Maertens' angular triad. Drawing by the author.
Fuente: Elaboration by the author.

In selecting these numbers, a marginal role might have played the singular work of the Bavarian economist Wilhelm Butte. In his *Prolégomènes de l'arithmétique de la vie humaine* (1812), immersed in Kantian apriorism as well as esoteric numerology, Butte had divided man's existence into nine-year climatic cycles, respect to the seven of the female life[10]. Certainly, Maertens' work is fueled by an organic conception of knowledge that nears him to the great men of the XVI and XVII centuries and that he shared with a few other scholars engaged in analogous scientific revision of the architectural principles. For example, in the same years the little-known Albert Eichhorn carried out a parallel research on the *akustische Maasstab* for theatrical architectures which is based on an original reinterpretation of Vitruvio's text by taking Euclide's division of the monochord rope as a unit of measure[11].

Of course, Maertens adopted other small licenses. For example, he almost ignored the width of the buildings – their extension on a horizontal plane – to focus on their height, the most important feature to influence human behavior. He also ignored the lower portion of the visual field below the horizon as if it does not affect the distance to look at a building from[12]. Moreover, he assumed that human gaze is kept steadily along a horizontal axis while it instinctively moves to look for the optical focus and the visual balance point of the building, tilting – also due to the differences in the ground – and altering the behavioral pattern assumption.

Human space and the Optical Scale

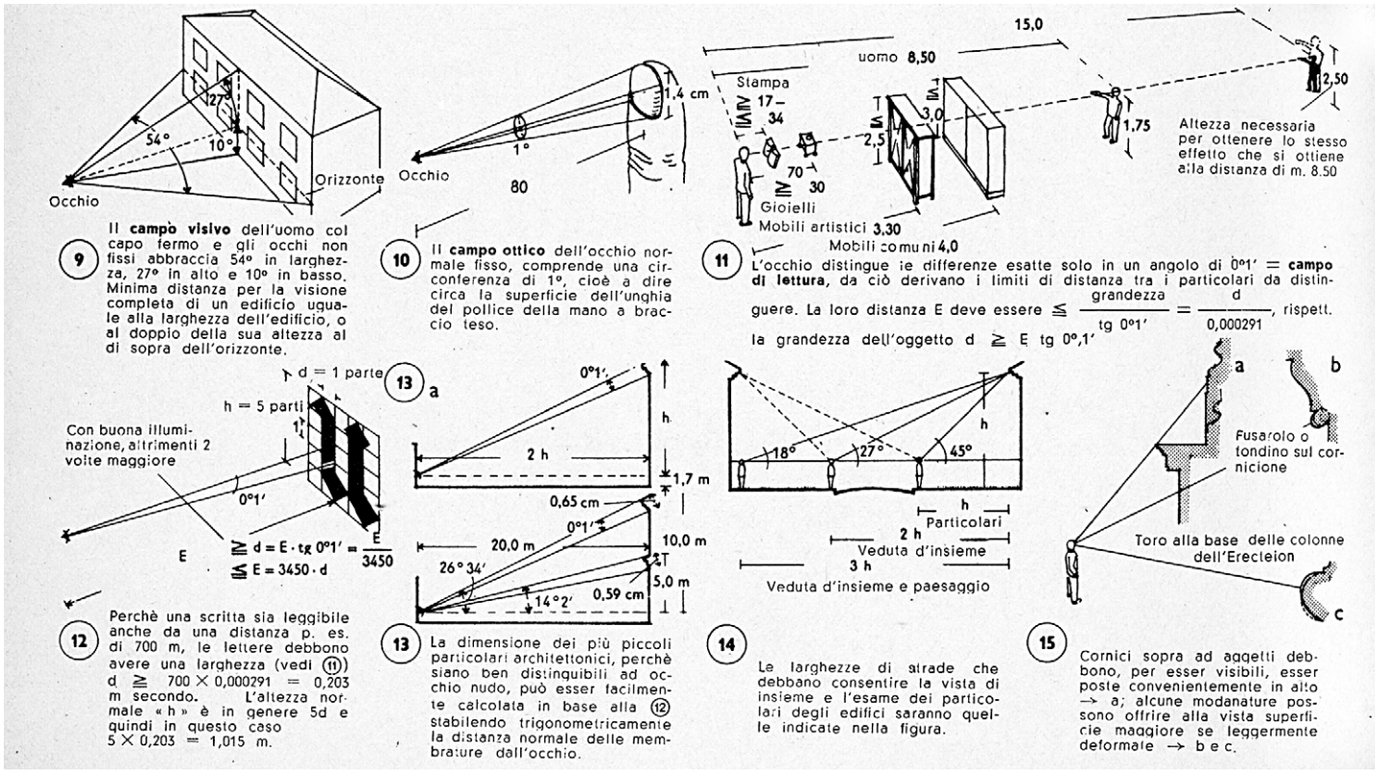
Maertens' work was a reference to the many designers interested in the aesthetic and narrative possibilities of *Raumkunst*: from Adolf Loos, who would be willing to size each single room according to the effect to exert on man [Fig. 7], to Le Corbusier, who elaborated the idea of architectural promenade as a sequence of visual effects. It could appear as a happy combination of Vischer's idealistic aesthetics and Fechner's empiricism[13] and it gradually contributed to the elaboration of *Gestaltungtheorie*, bringing a substantial theoretical and operational contribution to an aesthetics of vision based on the physiology of the eye. Maertens's ta-

10 Wilhelm Butte, *Prolégomènes de l'arithmétique de la vie humaine, contenant la classification générale des talens, l'échelle des âges de l'homme, et une formule d'évaluation de toutes les situations géographique: d'après un même système* (Paris- London- Landshut: Dentu, 1812), 125.

11 Albert Eichhorn, *Der akustische Maasstab* (Berlin: Schuster & Bufleb Architectur-Buchhandlung, 1899). I thank Jesper Cepl for this reference.

12 If one considers also the part of the view angle from the horizon plan to the base of the building, the angular triad would become 36, 54 and 90 degrees. In particular, the angle of 54° corresponds to the amplitude that has been measured observing people staring at medium and large objects at a distance of vision corresponding to the extension of the object itself. Marco Carpiceci and Maurizio Terrana, "L'immagine immersiva", *Disegnare. Idee e immagini* 30 (2005): 75.

13 Gerhard Fehl, "Camillo Sitte als 'Volkserzieher': Anmerkungen zum deterministischen Denken in der Stadtbaukunst des 19. Jahrhunderts", in *Städtebau Um Die Jahrhundertwende*, Gerhard Fehl and Juan Rodrîguez-Lores, eds. (Aachen: Deutscher Gemeindeverlag, 1980), 189.



[Fig. 8] Ernst Neufert's synthesis of Maertens's achievements in a Postwar Italian edition of his Manual.
Fuente: Ernst Neufert, *Enciclopedia pratica per progettare e costruire*, ed. Luigi Lenzi (Milano: Ulrico Hoepli, 1958), 18.

bles were recommended to the architects who design a well-proportioned living room, as can be read in the voluminous *Wohnhäuser* by Karl Weissbach[14] and still in 1927, fifty years after the first edition of the *Massstab*, Gustav Adolf Platz underlined his historical contribution in *Die Baukunst der neuesten Zeit*[15].

A summary of his ideas survived and was disseminated widespread, though largely anonymous and unconscious, thanks to Ernst Neufert. He redesigned and re-assembled Maertens' most important diagrams to ground the main core of the pages dedicated to visual perception in his *Bau-entwurfslehre*. Certainly, the publication of the manual since 1936 and its continuous updates contributed to providing these illustrations with the sense of a scientific tool useful to permeate the entire architectural design process of a determinism which was increasingly demanded by the industrialization of the constructive process [Fig. 8].

In particular, the dotted line cones Maertens had drawn in plans and sections to envision the look of pedestrians or tourists marked the imagination of architects and urban planners who aimed at turning the visualizations of their insights into scientific demonstrations. The visual cones, hitherto limited almost exclusively to the design of fortified and theatrical architecture, were adopted throughout the XX century as a visual tool to illustrate a number of different situations. The historian August Choisy adopted them in the analysis of the Athenian Acropolis while the architect Eugène Hénard used them to evaluate the Parisian vehicular traffic. Alexander Klein adopted them in his diagrams to demonstrate the inefficiency of traditional buildings while Le Corbusier used them to suggest a panoramic relationship between architecture and landscape, like in the projects for Algiers. Luigi Moretti used the cones to visualize the optical control of spatial sequences in the rhetorical apparatus of Fascist architecture[16] while Gio Ponti did it to "narrate" the perceptual richness of residential spaces, like in Villa Planchart at Caracas.

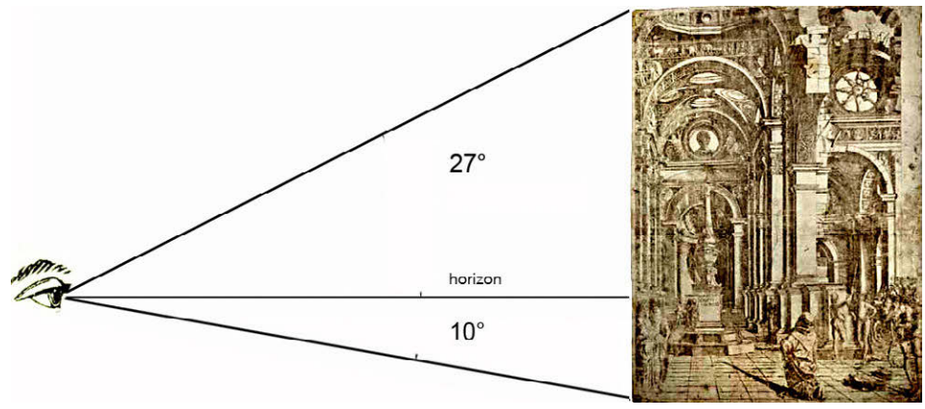
At the time of Ponti, Maertens ideas had already been relaunched in America by Hans Blumenfeld at a conference in Yale and then in an article[17], which had the importance of providing a common scientific basis not only to Rudolf Arnheim's study on visual perception[18] but also to Christopher Alexander's subsequent

14 Karl Weissbach, *Wohnhäuser* (Stuttgart: Arnold Bergsträsser Verlagbuchhandlung, 1902), 13–17. See also: Jesper Cepl, "Vom 'Palaststil' zur 'Wohnmaschine' – Die Transformation des städtischen Raumgefüges nach 1900, oder Vorläufige Bemerkungen über ein vergessenes Formproblem", *Wolkenkuckucksheim*, 9 (2004): 1, http://www.cloud-cuckoo.net/openarchive/wolke/deu/Themen/041/Cepl/cepl.htm (accessed October 29, 2012).

15 Gustav Adolf Platz, *L'architettura della nuova epoca*, Michele Stavagna, ed. (Bologna: Editrice Compositori, 2009), 213–214.

16 The deterministic visual approach of Luigi Moretti, who knew Maertens' ideas through the mediation of Gustavo Giovannoni, was both formal and substantial. On the occasion of the 1960 Olympics in Rome, Luigi Moretti and mathematician Bruno De Finetti designed some sports facilities whose form is closely functional to the optimum visual relationship between the points of the court and those of the seats, identified by a visual appetite equation. Moretti named "Parametric Architecture" this design principle that derives the architectural form from the calculation of optical efficacy. See Bruno Reichlin, "Figure della spazialità 'Strutture e sequenze di spazi' versus 'lettura integrale dell'opera'", in *Luigi Moretti. Razionalismo e trasgressività tra barocco e informale*, Bruno Reichlin and Letizia Tedeschi, eds. (Mendrisio: Fondazione del Moderno-Electa, 2010), 29.

17 Hans Blumenfeld, "Scale in Civic Design", *Town Planning Review* 24 (1953): 35–46.



[Fig. 9] Also this famous interior of a ruined church or temple with figures, engraved in 1481 by Bernardo Prevedari after a drawing by Bramante's is virtually seen under a 27° wide visual angle. Diagram by the author. Fuente: Elaboration by the author.

methodological researches set in 1977 in *A Pattern Language: Towns, Buildings, Construction*, and to Proxemics' research Edward T. Hall presented in 1966 in *The Hidden Dimension*. Kevin Lynch's investigations in urban and territorial settings were marked by Maertens' observations, as well[19]. For example, Lynch suggested a ratio between 1:2 and 1:4 between height of enclosing walls and a space dimension is most "comfortable" with the sense of "enclosure", which is lost when the ratio is beyond 1:4 and if less than 1:1, the space being like a "pitch or trench"[20].

The Visual Planning

The main field of application of the *Optische-Maassstab* was certainly the urban planning, especially those experiences that critically recovered the picturesque tradition, giving rise to the concept of Townscape and Visual Planning[21]. Eventually, Maertens had the ambition to find a scientific justification for the compositional principles practiced for centuries even if according to several different aims [Fig. 9]. Although the perspective figurative revolution had taken place in Florence at the beginning of the XIV century, there are only few written notes about the perceptual opportunities offered by the squares, like Leon Battista Alberti's in the epigraph of this article. Only in the second half of XVI century, when Michelangelo's innovative square at the Campidoglio was still under construction, Andrea Palladio defined the squares like those "wide places left in the cities" in order to see "the appearance of some beautiful *fabrica* and mostly of some Temple"[22]. The XVII century records a new awareness about the relationship between the right distance and the visual effect of architecture. Jules Hardouin-Mansart questioned on the value of the incidence of the visual angle on the perception of his urban projects[23]. Writing about the new axis of the Chapel of the Sorbonne, in a letter to Cardinal Richelieu, it is noted that "without the opening of this avenue and the square, the church would not emerge the half of what emerges now"[24]. Gian Lorenzo Bernini is possibly an international exporter of this new sensitiveness. In order to "see perfectly"[25] the facade of his Louvre, he designed a square that was equal to one and a half the height of the palace, a ratio corresponding to Maertens' visual angle of 27°. Elsewhere Pope Alexander VII, his fellow friend, asked for a wide square in front of the church of Santa Maria in Portico in Rome, to be "surrounded by decorated palaces"[26].

Charles De Brosses, in his Roman residence in the winter between 1739 and 1740, claimed the Italians have the visual art of transforming nature into art and art in nature: "What is wonderful in Rome is the way to arrange the points of view and to set up the display of the individual objects. This art is the principle that contributes in lesser form to giving the city this air of greatness. It cannot be felt at all in Paris"[27].

18 Although implicitly present in much of his work, Arnheim recognized explicitly Maertens' centrality only in *The Dynamics of Architectural Form* (Berkeley: University of California Press, 1977), 128–131.

19 See also: Erik Ghenoiu, "The resurgence of visual urbanism in the American architectural discourse, 1954–1972", *The Journal of Architecture* 17, 5 (2012): 791–805.

20 Kevin Lynch, *Site Planning* (Cambridge, MASS: The MIT Press, 1971), 194. Among the many applications of the *Maaastab* beyond the deterministic tasks Maertens had conceived it for, one cannot forget the angular optical theory that supports the studies led by Doxiadēs after the Second World War on the monumental complexes of the ancient Greece. See: Kōnstantinos Apostolou Doxiadēs, *Architectural space in Ancient Greece* (Cambridge, MASS: The MIT Press, 1972).

21 Nikolaus Pevsner and Mathew Aitchison, eds., *Visual Planning and the Picturesque* (Santa Monica, CA: Getty Research Institute, 2010).

22 Andrea Palladio, *Quattro Libri dell'Architettura* (Pordenone: Edizioni Studio Tesi, 1992), 230.

23 Jean-Pierre Babelon and Claude Mignot, eds., *Francois Mansart. Le genie de l'architecture* (Paris: Gallimard, 1998).

24 Claude Mignot, "Mutazioni urbane", in *I trionfi del Barocco. Architettura in Europa 1600-1750*, Henry A. Millon, ed. (Milano: Bompiani, 1999), 328.

25 Paul Fréart de Chantelou, *Journal de Voyage du Cavalier Bernin en France* (Clamecy: Pandora, 1981), 99.

26 Richard Krautheimer, *The Rome of Alexander VII, 1655-1667* (Princeton, NJ: Princeton University Press, 1985), 82.

27 Mignot, "Mutazioni", 329.

The Parisian situation was to change dramatically in just a century and the experience of the tree-lined boulevards opened by the Baron Hausmann fascinated a whole generation of architects. In their eyes, Paris became a "transparent" city: drawing one's own itinerary seemed as easy as to move into a "well-designed home [*Heimat*]"[28].

Visual Planning and Optical Scale

At the end of XIX century, an unprecedented attention to the urban perception of a mobile subject stimulated the spread of scientific planning criteria related to human physiological characteristics. As already pointed out by Brian Ladd[29] and, most recently, by Ákos Moravánszky[30], Camillo Sitte was the main protagonist to bring city planners back to the point of view of a man walking. As a scholar of Piero della Francesca and Italian perspective[31], he considered streets and squares as active components in the construction of the image of the city. He analyzed the contribution to the visual effect on the observer and re-evaluated the continuity offered by staircases, galleries and arcades in a perceptual and spatial sense, whose design and scale psychologically refer to the experience of internal spaces. Still, he did not explicitly mention Maertens' work, perhaps because he considered obvious the ratios he had identified or simply because he did not aim at transforming urbanism into a science. Although both "share the desire to establish a method by which to judge the aesthetic outcome of urban planning"[32], Sitte did not provide scientific keys to a valid insight into urban kinetic perception. In the end, the success of his book *Der Städtebau nach seinen Künstlerischen Grundsätzen* (1889) is also due to the popular approach, accessible language and synthetic iconography while instead Maertens' meticulous treatise may result hermetic and tiring.

Anyway, the immediate success of Maertens' ideas in the field of urban planning is evidenced by the booklet *Optische-Maass für den Städte-bau* (1890), a synthetic and cheap summary of his researches expressly targeted to city historians and urbanists. It possibly influenced Raymond Unwin, who found a methodological inspiration for elaborating the principles of "informal planning" and to give back to vision a central role in urban organization as a sequence of paintings-like visual experiences. Most of all, the town planning manuals of Gurlitt, Stübben[33], and Brinckmann[34] immediately embraced the scientific method and results of Maertens' studies. They marked profoundly architects like Theodor Fisher and his follower Heinz Wetzel from the Stuttgart school who was deeply inspired by his new consciousness of vision. "Wetzel was convinced of the existence of certain universal rules that had to be applied to create spatial order. To him, topography was the key. The highs and lows were decisive. The layout of the streets had to be decided upon *Schwelle* (threshold) and *Einschlag* (impact). According to Wetzel, *Längenvisierbruch* (a change in the street's gradient) should coincide with *Horizontalvisierbruch* (a shift in street direction or an offset in the building line) to produce a *Raumbild* (the picture produced by enclosed space) that convincingly seemed *gewachsen* (grown) instead of *gemacht* (made)"[35]. It is also interesting to note that Fischer's courses at Stuttgart were attended by some of the most original and sensitive personalities of the XX century, such as Dominikus Böhm, Hugo Häring, Ernst May, Erich Mendelsohn, J.J.P. Oud, Bruno Taut and Sigurd Lewerentz.

With his *Town Planning: Past, Present and Possible*, in 1902 Inigo Triggs contributed to disseminate Maertens' studies even to America. Still in 1922, Werner Hegemann and Elebert Peets adopted his criteria in their urban planning manual, ambitiously entitled *The American Vitruvius*. They not only found the dimensional limit of the square in the 1:3 ratio (corresponding to 18°) but above all explicitly referenced to the "modern investigations" by Maertens by applying the visual

28 Josef Stübben, *Paris in Bezug auf Strassenbau und Stadterweiterung* (Berlin: Ernst & Korn, 1879), 377.

29 Brian Ladd, *Urban Planning and Civic Order in Germany: 1860-1914* (Cambridge, MASS: Harvard University Press, 1990).

30 Ákos Moravánszky, "The optical construction of urban space: Hermann Maertens, Camillo Sitte and the theories of 'aesthetic perception'", *The Journal of Architecture* 17, 5 (2012): 655–666.

31 Some of Sitte's unedited manuscripts contains deep studies on the renaissance perspective of Piero della Francesca. See: Charles C. Bohl and Jean-François Lejeune, *Sitte, Hegemann and the metropolis: modern civic art and international exchanges* (London: Routledge, 2009), 75.

32 Ladd, *Urban Planning*, 121.

33 Stübben listed quite literally Maertens' achievements in the paper he wrote in 1885 and discussed in the International Engineering Congress of the Columbian Exposition of 1893 in Chicago during the World Exposition. An English version of it was included in the proceedings: Josef Stübben, "Practical and Aesthetic Principles for the Laying Out of Cities", *Transactions of the American Society of Civil Engineers* 29 (1893): 718–736.

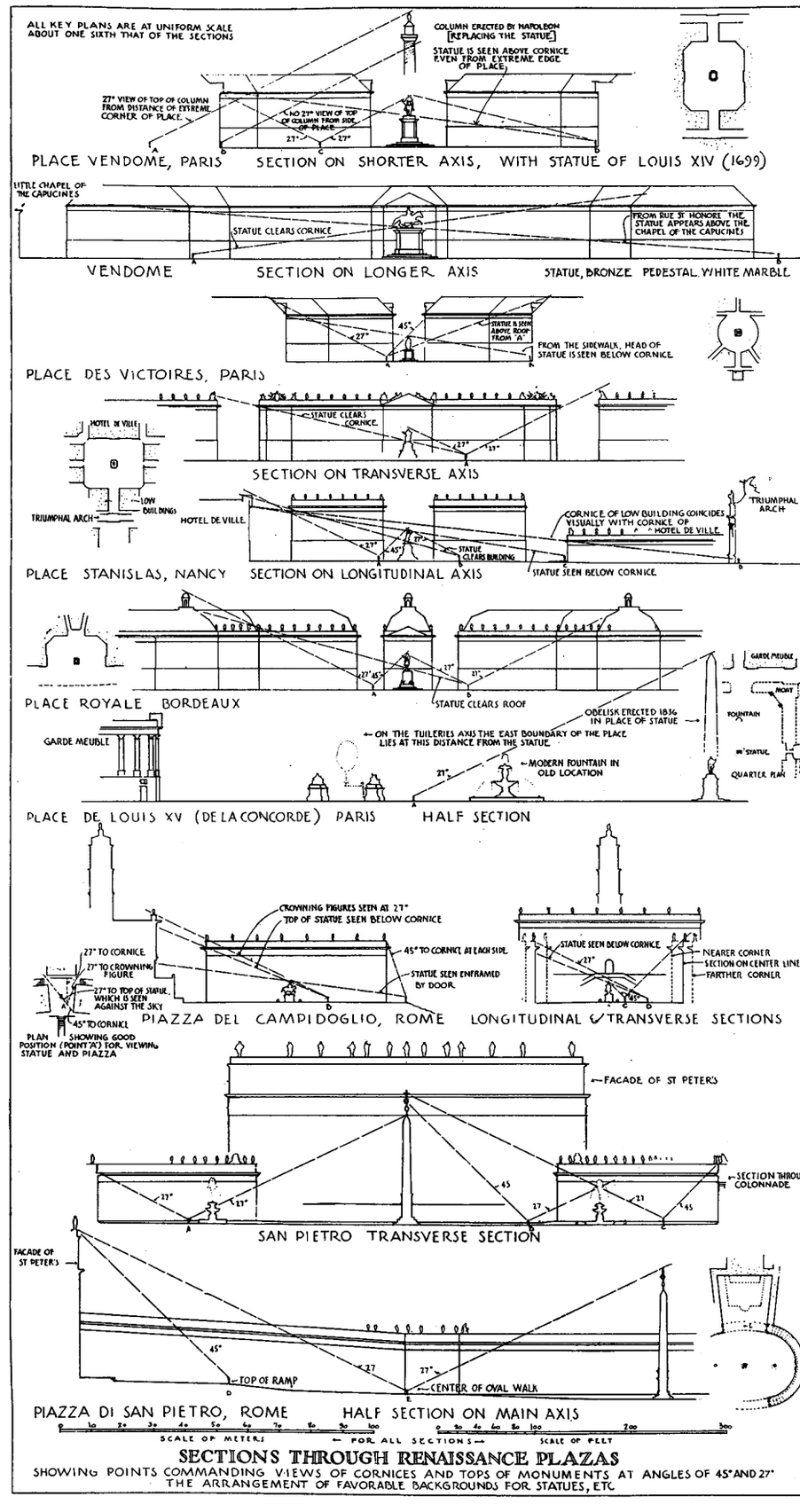
34 Brinckmann dedicated an entire work to Maertens' contribute to urban perception: Albert Erich Brinckmann, "Der optische Maßstab für Monumentalbauten im Stadtbau", *Wasmuths Monatshefte für Baukunst* 2 (1914).

35 Jasper Cepl, "Townscape in Germany", *The Journal of Architecture* 5 (2012): 777.

FABIO COLONNESE

The Geometry of Vision: Hermann Maertens' Optical Scale for a Deterministic Architecture

La Geometría de la Visión: la Escala Óptica de Hermann Maertens para una Arquitectura Determinista



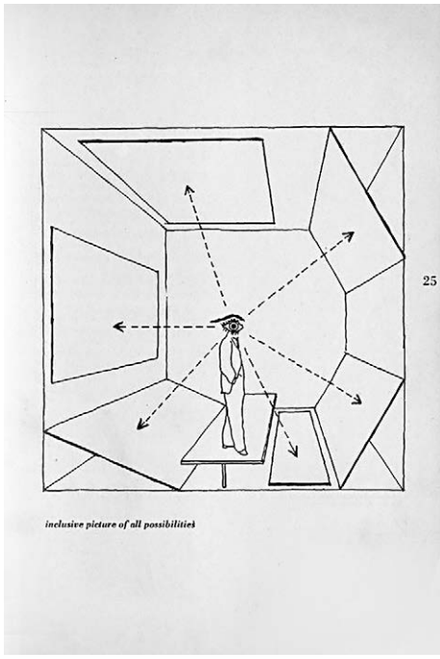
[Fig. 10] Hegemann and Peets' applications of Maertens' approach to squares in Rome and Paris.
Fuente: Werner Hegemann, Elbert Peets, *The American Vitruvius* (New York, NY: Architectural Book Publishing 1922), fig. 219.

angles of 18, 27 and 45 degrees on the profiles of the main Roman and Parisian squares in the table titled *The Size of Renaissance Plazas*[36] [Fig. 10].

Critical reception and abuse

Hermann Maertens's outcomes were not acrimoniously assimilated. In the global reconsideration of the XX century city in terms of circulation and undecorated volumes, some scholars judged Maertens' inquiries as antiquated and reactionary, anchored to the reassuring static nature of the Renaissance perspective.

36 Werner Hegemann and Elbert Peets, *The American Vitruvius: An Architects' Handbook of Civic Art* (New York, NY: Architectural Book Publishing, 1922), 42–44.



[Fig. 11] Herbert Bayer, Diagram of the Extended Field of Vision, 1935.
Fuente: Herbert Bayer, "Fundamentals of Exhibition Design", in *PM: an intimate journal for advertising production managers, art directors and their associates* (New York: PM Pub. Co., 1939-40), 25.

For example, Ildefonso Cerda analyzed the modern city around the key notions of rest and movement, comforted by a wealth of references to biology, anatomy and medicine, in his *Teoría general de l'urbanización* (1867).

In his inaugural speech at the University of Leipzig in 1893, entitled *Das Wesen der Architektonischen Schöpfung*, or "the essence of architectural creation", August Schmarsow began to develop the perceptive empiricism in a foundational principle, by assuming the bodily movement through space as the very essence of architecture and condemned the stationary perception of form, as proposed in the same years by Wölfflin and indirectly by Maertens himself.

Anyway, it took decades to evolve the Renaissance-born vision scientifically redefined by Maertens in something totally new. Quite in the same years in which Neufert was customizing Maertens' schemes for his manual, Herbert Bayer, another formerly student at the Bauhaus, was elaborating an innovative exhibition structure for a new dynamic and immersive perception, immortalized in 1935 in the famous *Diagram of the Extended Field of Vision* [Fig. 11].

Maertens was criticized not only for the implicit stillness of his visual analyses but also for the presupposed frontal vision of the work which prevails in his schemes. Stübben found that his formulas were likely to produce squares that look too dilated[37]. Brinckmann, who was author of analysis and schemes based on Maertens' work, tried to temper his stainless determination through a series of psychological considerations. He emphasized the role of optical illusions and that of the elements referable to the human scale in the optical measurement of building bodies. For example, he recalled the different effect of buildings more or less cut out, articulated or stylistically heterogeneous: a Gothic cathedral is articulated in a myriad of parts and may looks larger than a building of the same size in Doric or industrial style[38].

The visual approach of Maertens deeply binds the shape and position of the architectural body to its immediate spatial surroundings, making them indissolubly bound. If it is necessary to preserve a specific free distance for the best enjoyment of the monument and volume of the church, then the surrounding visibility area becomes implicitly a part of the building itself, a sort of visual servitude. Quite the same could be claimed for the path route considered propaedeutic to the visual discovery and exploration of the building.

While this observation contributed to a mature concept of the city as an interconnected system of spaces and volumes, on the other hand it could legitimate also the idea of the city as a collection of monuments. Describing the Cologne Cathedral, for example, Maertens asserted "it is therefore justified the use of leaving space around the most valuable buildings (churches), although this can lead to demolitions"[39]. This and other similar statements may have had more than one consequence on the historical-operational conception of Gustavo Giovannoni. In 1913, he elaborated the famous and notorious "Teoria del diradamento edilizio" that was occasionally applied in the historic center of Rome to reestablish hygienic conditions and visibility to the monuments, at the expense of not only the medieval fabric but also of important buildings. Giovannoni knew *Der Optische-Maassstab*. A copy of the second edition of the book was catalogued in S. Luca Academy's library and he explicitly mentioned it both in *Vecchie città ed edilizia nuova*[40] and in his monographic work on Antonio da Sangallo the Younger[41]. This could be a demonstration of the way Maertens' work affected the modus operandi of architects as both urban planners and art historians but at the same time, of the risks of abusing his observations on the optimization of the perception of monuments in town.

37 Josef Stübben, *Der Städtebau. Handbuch der Architektur* (Darmstadt: Arnold, 1890), 167.

38 Albert Erich Brinckmann, "Der optische Massstab für Monumentalbauten im Stadtbau", *Wasmuths Monatshefte für Baukunst* 1 (1914): 57; Reichlin, "Figure della spazialità", 29.

39 Maertens, *Der Optische-Maassstab,* 1877, 10.

40 "Le condizioni di ottimo apprezzamento di edifici (…) sono state (…) così stabilite: quando si vuole avere la percezione dei particolari, occorre che la distanza del punto di vista sia uguale all'altezza; quando il principale valore è dato dai rapporti di massa di un edificio col suo ambiente, si giunge al triplo; quando infine l'effetto è di ordine pittoresco, al quadruplo, rapporto che è bene non superare. Rientra così il concetto dello spazio racchiuso e definito necessario per l'apprezzamento". Gustavo Giovannoni, *Vecchie città ed edilizia nuova* (Torino: UTET, 1931), 128.

41 Gustavo Giovannoni, *Antonio da Sangallo, il Giovane* (Roma: Centro Studi di Storia dell'architettura, 1959), I, 162, note 2.

Conclusions

Though today scarcely known, Hermann Maertens's work initially received a remarkable credit from his colleagues and not only. Basing on the physiological observations of Helmholtz and Donders, Maertens investigated scientifically the question of the optical scale in the perception of human environment, from the scale of the artwork in a room to that of a building in a large square. The arithmetic determinism of his approach and the amount of data and observations in his books provided some modern architects with tools to partially fight the unconscious components of the design process according to the industrial-inspired idea of a *Neue Sachlichkeit.* At the same time, they re-centered the mission of the designer around human body and sensorial features, even if according a Renaissance-perspective static vision, with an attention to proportion that will be recovered by few modern architects, like Le Corbusier.

The dissemination of Maertens' results was limited by the complexity of his treatises as well the lacking of an organic translation of them. It gradually exhausted in the years between the two world wars and the results of his researches were transmitted partially or unconsciously, thanks to the reproduction of a few of his illuminated diagrams or some rough written synthesis. The Optical Scale did not strike deep into the architect's practice, confined in small appendixes of the most diffused design manuals or graphic devices applied on a plan to remind the presence of a vantage point or to attribute at least a semblance of science to architectural processes and products. From this point of view, his story confirms the congenital difficulty, in some ways ever present, of transforming the design practice into a properly scientific process, as if the designer felt his creative autonomy threatened by principles, methods and tables. But even if an almost indirect way, Martens' ideas fertilized a ground that is common to a number of interdisciplinary studies that deeply marked the development of urban and architectural culture from the 1960s. Even today, the idea that there is a proper way to look at a building, with a precise distance according to the finality and the definition of the detail, is something that could be very useful in the production and use of visual interfaces and images generated by the computer often with no awareness of the physiological behavior of the human eye.

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